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⑤膜厚の測定方法及び装置

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明　細　書

1、発明の名称

膜厚の測定方法及び装置

2、特許請求の範囲

(1) 真空中においた薄膜試料に電子線を照射し、その透過電流を測定して前記薄膜試料の膜厚を測定することを特徴とする膜厚の測定方法。

(2) ベルジャー及び真空ポンプを主体とした真空系と、真空中においた薄膜試料に電子線を浴びせる電子銃とその電源を主体とした入射電子系と、電流計を主体とした前記薄膜試料の透過電流測定系とから構成したことを特徴とする膜厚の測定装置。

(3) 前記薄膜試料が、蒸着基板に形成された蒸着膜である特許請求の範囲第2項に記載の膜厚の測定装置。

(4) 前記蒸着膜の入射電子系よりの透過電流を測定する測定系が比較器を介して前記蒸着膜の蒸着制御電源に接続されている特許請求の範囲第2項に記載の膜厚の測定装置。

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(5) 前記入射電子系が電子レンズを備えている特許請求の範囲第2項から第4項のいずれかに記載の膜厚の測定装置。

3、発明の詳細な説明

本発明は、例えば蒸着膜などの薄膜試料の膜厚測定に関するものである。

従来、膜厚を測定する方法としては、各種の顕微鏡を用いる方法や光の干渉や吸収を利用する方法などがある。しかし、これらの方法では測定できる膜の厚さに制限があり特に薄い膜の膜厚測定が困難であった。

また、試料薄膜表面に加速したイオンを衝突させ、膜表面より放出される2次イオン、光などを検出する方法もある。しかし、これらの方法は破壊測定法であり、膜厚を測定しながらその膜を成長させることは不可能であった。

本発明は非破壊的に膜厚を測定するとともに膜厚を測定しながら膜を成長させることができる方法および装置を提供するものである。

次に本発明の原理を説明する。一般に物質は固

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有の抵抗を有している。真空中に存在する物質に電子線を照射すると、物質によって後方散乱を受けた電子と、物質を透過した電子とを観測することができる。電子線の入射面積を一定とした場合、厚みが増大するにつれて透過電流は減少する。ある一定の厚さを有する基板上に蒸着などによって形成された薄膜の表面へ電子線を入射させると、薄膜と基板を透過した電流を測定することができる。この際、基板による透過電流は一定であるから、蒸着薄膜の膜厚変化を透過電流の変化によって検知できる。

従って、予め基板に用いる物質とその厚みに対する透過電流との関係、及び薄膜形成物質とその厚みに対する透過電流との関係を求めておけば、膜厚未知の薄膜の膜厚を知ることができる。

本発明はこのような原理に基づいたものであり、以下その実施例により詳細に説明する。第1図は本発明で用いた膜厚測定装置の概念図である。図において、真空ポンプ1により真空に脱気されたベルジャー2の中に薄膜試料3が設置され、この薄膜試料3の表面へ、制御電源4により駆動される電子銃5から放射された電子線が入射する。この際に薄膜試料3を透過する透過電流を電流計6により検出して膜厚を測定するものである。なお、7は電子銃5の集束用電子レンズである。

第2図に示すように基板上に形成された膜厚が0の場合(形成されなかった場合)測定される透過電流は基板自体の透過電流aであり、蒸着膜等の膜厚が順次増大するに従って曲線Cに沿って透過電流が減少する。電流が透過できなくなるほどの膜厚bになった時、透過電流は0となる。なおこの曲線Cの曲率は物質によって決まる。

従って、予め蒸着物質を決定し、その物質の曲線Cを求めておけば、電子線照射時の透過電流を検知することによりその膜厚を知ることができる。

第2図の点bはある物質について入射電圧を一定の値にしたときに得られる測定可能な最大膜厚である。なお、この値は第3図に示すようにある物質については曲線dに示す如く加速電圧に従って増大する。この曲線dの曲率は物質により決まる。

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第4図は本発明の測定方法の実施の一例を示す装置の概略図である。真空ポンプ1により真空に脱気されたベルジャー2の中で、蒸着基板8には制御電源9により制御された蒸着源10により蒸着膜3が形成される。この蒸着膜3の表面へ制御電源4により制御された電子銃5から放射された電子線流を浴びせ、電流計6によりその透過電流を測定する。この測定装置により基板8上に形成されつつある蒸着薄膜3の膜厚を非破壊的に、その場で測定することができる。

また、蒸着膜3の膜厚を自動制御しようとする場合には電流計6で測定した膜3の透過電流を比較器11で比較し、所定の膜厚が得られた時点で蒸着制御電源9を停止させればよい。

さらに、蒸着膜の膜厚の面内分布を知りたいときには入射電子系の電子レンズ7により、蒸着膜の入射電子線の入射位置をX−Y方向に移動させ、各位置での透過電流を測定することで求めることができる。

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このように本発明における膜厚の測定方法及び装置では次のような効果が得られる。

(1) 非破壊的に薄膜試料の膜厚測定ができる。

(2) 非常に薄い膜から比較的厚い膜まで広範囲に測定できる。

(3) 蒸着膜が薄膜試料の場合、蒸着を行いながらその膜厚をその場で測定することができる。

(4) 蒸着膜厚の自動制御を行うことができる。

(5) 薄膜の膜厚の面内分布を求めることができる。

4、図面の簡単な説明

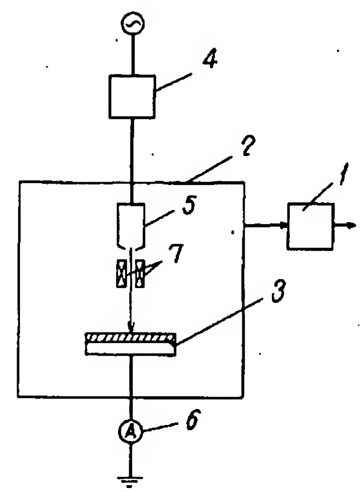
第1図は本発明の膜厚測定装置の一例を示す概念図、第2図は入射電子線の加速電圧を一定の値としたときに得られる薄膜の膜厚と透過電流との関係を示す図、第3図は特定の薄膜形成物質について、入射電子線の加速電圧と測定可能な最大膜厚との関係を示す図、第4図は本発明の蒸着膜厚測定装置の一実施例における略図である。

1……真空ポンプ、2……ベルジャー、3……薄膜試料、4……電子銃の制御電源、5……電子銃、6……電流計、7……電子銃の集束用電子レ

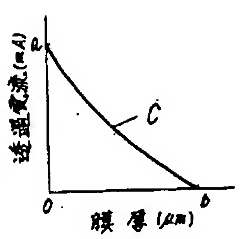
ンズ、8……蒸着基板、9……制御電源、10……蒸着源、11……比較器。

代理人氏名 弁理士 中 尾 敏 男 ほか1名

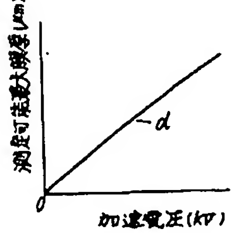
第 1 図



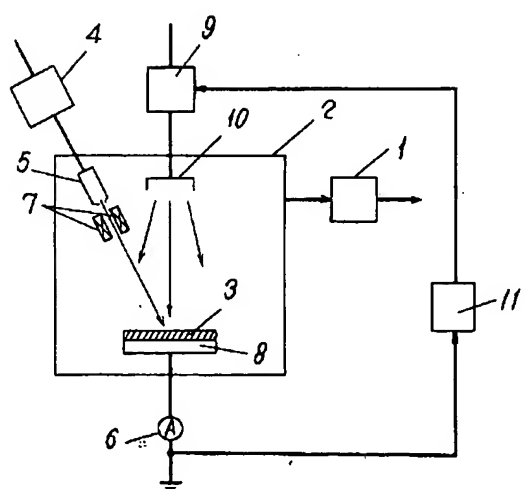
第 2 図



第 3 図



第 4 図



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(54) FILM THICKNESS MEASUREMENT METHOD AND APPARATUS

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SPECIFICATION

1. Title of the Invention

FILM THICKNESS MEASUREMENT METHOD AND APPARATUS

2. Claims

(1) A film thickness measurement method which is characterized by the fact that a thin film sample placed in a vacuum is irradiated with an electron beam, and the thickness of this thin film sample is measured by measuring the transmission current.

(2) A film thickness measurement apparatus which is characterized by the fact that this apparatus is constructed from a vacuum system that comprises mainly a bell jar and a vacuum pump, an incident electron system that comprises mainly an electron gun that irradiates a thin film sample placed in a vacuum with an electron beam, and a power supply for this electron gun, and a transmission current measurement system for the above-mentioned thin film sample that comprises mainly an ammeter.

(3) The film thickness measurement apparatus according to Claim 2, wherein the above-mentioned thin film sample is a vapor deposition film formed on a vapor deposition substrate.

(4) The film thickness measurement apparatus according to Claim 2, wherein the measurement system that measures the transmission current from the incident electron system for the above-mentioned vapor deposition film is connected to a vapor deposition control power supply for the above-mentioned vapor deposition film via a comparator.

(5) The film thickness measurement apparatus according to any of Claims 2 through 4, wherein the above-mentioned incident electron system comprises an electron lens.

3. Detailed Description of the Invention

The present invention relates to the measurement of the thickness of thin film samples such as vapor deposition films.

Conventionally, film thickness measurement methods have included methods using various types of microscopes, methods utilizing light interference or absorption, and the like. In the case of these methods, however, there are limits to the film thicknesses that can be measured, and it is especially difficult to measure the thickness of thin films.

Furthermore, there are also methods in which accelerated ions are caused to collide with the sample thin film, and secondary ions or light, etc., emitted from the film surface are detected.

However, these methods are destructive measurement methods, and it is impossible to grow the film while measuring the film thickness.

The present invention provides a method and apparatus that make it possible to measure the thickness of a film in a non-destructive manner, and to grow the film while measuring the film thickness.

Next, the principle of the present invention will be described. Generally, a substance has a specific [electrical] resistance. When a substance that is present in a vacuum is irradiated with an electron beam, electrons that are caused to undergo back scattering by the substance and electrons that are transmitted through the substance can be observed. In a case where the incident area of the electron beam is constant, the transmission current decreases with an increase in the thickness [of the substance]. When an electron beam is caused to be incident on the surface of a thin film formed by vapor deposition or the like on the surface of a substrate that has a certain fixed thickness, the current that passes through the thin film and substrate can be measured. In this case, since the transmission current attributable to the substrate is constant, variations in the thickness of the vapor deposition thin film can be detected by variations in the transmission current.

Accordingly, if the relationship between the substance used for the substrate and the transmission current corresponding to the thickness of this substance, and the relationship between the substance from which the thin film is formed and the transmission current corresponding to the thickness of this substance, are determined beforehand, the thickness of a thin film of unknown thickness can be ascertained.

The present invention is based on such a principle, and will be described in detail below in terms of an embodiment. Figure 1 is a schematic diagram of the film thickness measurement apparatus used in the present invention. In this figure, a thin film sample 3 is placed inside a bell jar 2 which is evacuated to a vacuum by means of a vacuum pump 1, and an electron beam that is emitted from an electron gun 5 driven by a control power supply 4 is caused to be incident on the surface of this thin film sample 3. The film thickness is measured by detecting the transmission current that passes through the thin film sample 3 in this case by means of an ammeter 6. Furthermore, 7 indicates the focusing electron lens of the electron gun 5.

As is shown in Figure 2, the transmission current that is measured in a case where the thickness of the film that is formed on the substrate is 0 (i.e., in a case where no film is formed) is the transmission current *a* of the substrate itself, and the transmission current decreases along the curve *C* as the thickness of the vapor deposition film or the like successively increases.

When [the thickness reaches] a film thickness *b* which is such that no current is transmitted, the transmission current becomes 0. Furthermore, the curvature of this curve *C* is determined by the substance involved.

Accordingly, if the vacuum-deposited substance is determined, and the curve *C* of this substance is determined in advance, the film thickness can be ascertained by detecting the transmission current in the case of electron beam irradiation.

Point *b* in Figure 2 is the maximum measurable film thickness that is obtained when the incident voltage is set at a constant value for a certain substance. Furthermore, as is shown in Figure 3, this value increases in accordance with the acceleration voltage for a given substance as indicated by the curve *d*. The curvature of this curve *d* is determined by the substance that is involved.

Figure 4 is a schematic diagram of an apparatus showing one example of the working of the measurement method of the present invention. A vapor deposition film 3 is formed by means of a vapor deposition source 10 (controlled by a control power supply 9) on a vapor deposition substrate 8 inside a bell jar 2 which is evacuated to a vacuum by means of a vacuum pump 1. The surface of this vapor deposition film 3 is irradiated with an electron beam current that is emitted from an electron gun 5 controlled by a control power supply 4, and the [resulting] transmission current is measured by means of an ammeter 6. The film thickness of the vapor deposition thin film 3 can be measured on-site in a non-destructive manner by means of this measurement apparatus while the vapor deposition thin film 3 is formed on the substrate 8.

Furthermore, in cases where it is desired to control the film thickness of the vapor deposition film 3 automatically, [this can be accomplished by using] a comparator 11 to compare the transmission current [values] of the film 3 measured by the ammeter 6, and stopping the vapor deposition control power supply 9 at the point in time at which the specified film thickness is obtained.

Furthermore, in cases where it is desired to ascertain the in-plane distribution of the film thickness of the vapor deposition film, this can be determined by moving the incident position of the incident electron beam on the vapor deposition film in the X-Y direction by means of the electron lens 7 of the incident electron system, and measuring the transmission current at respective positions.

Thus, the following effects are obtained in the case of the measurement method and apparatus of the present invention:

(1) The film thickness of thin film samples can be measured in a non-destructive manner.

(2) Measurements can be made in a broad range, ranging from extremely thin films to relatively thick films.

(3) In cases where the thin film sample is a vapor deposition film, the film thickness can be measured on-site while performing vapor deposition.

(4) Automatic control of the thickness of vapor deposition films is possible.

(5) The in-plane distribution of the film thickness of thin films can be determined.

4. Brief Description of the Drawings

Figure 1 is a schematic diagram which shows one example of the film thickness measurement apparatus of the present invention. Figure 2 is a graph which shows the relationship between the transmission current and the film thickness of the thin film that is obtained when the acceleration voltage of the incident electron beam is maintained at a constant value. Figure 3 is a graph which shows the relationship between the maximum measurable film thickness and the acceleration voltage of the incident electron beam for a specified thin film forming substance. Figure 4 is a schematic diagram of one embodiment of the vapor deposition film thickness measurement apparatus of the present invention.

1... Vacuum pump; 2... Bell jar; 3... Thin film sample; 4... Electron gun control power supply; 5... Electron gun; 6... Ammeter; 7... Focusing electron lens of electron gun; 8... Vapor deposition substrate; 9... Control power supply; 10... Vapor deposition source; 11... Comparator.

Name of Agent: Toshio Nakao, Patent Attorney, and one other

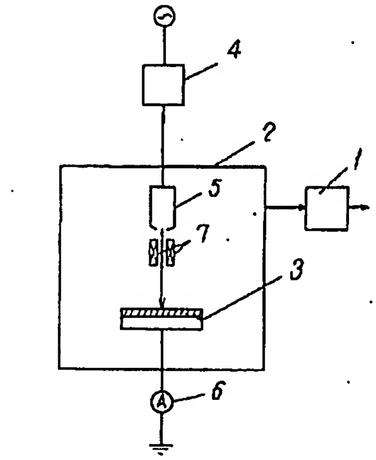

Figure 1

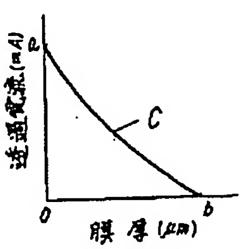

Figure 2

Y axis: Transmission current (mA)

X axis: Film thickness (μm)

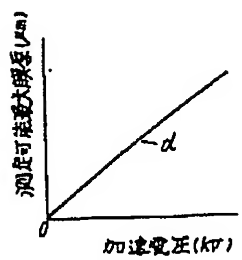

Figure 3

Y axis: Maximum measurable film thickness (μm)

X axis: Acceleration voltage (kV)

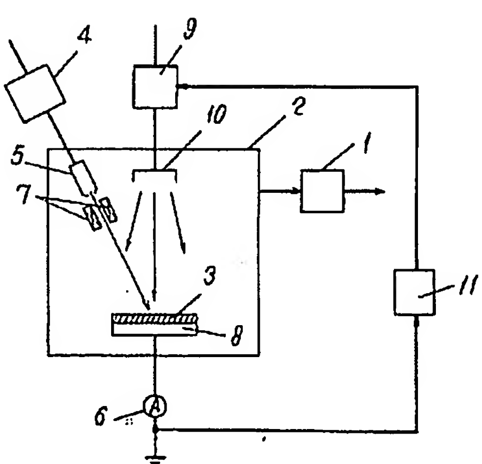

Figure 4